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# DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150699

## DESIGN DATA BROCHURE: SOLAR HOT WATER SYSTEM

Prepared from documents furnished by

Solar Engineering and Manufacturing Company  
1054 NE 43rd Street  
Ft. Lauderdale, Florida 33334

Under Contract NAS8-32247 with

National Aeronautics and Space Administration  
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy



(NASA-CR-150699) DESIGN DATA BROCHURE:  
SOLAR HOT WATER SYSTEM (Solar Engineering  
and Mfg. Co.) 21 P HC A02/ME A01 CSCL 10A

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# U.S. Department of Energy



## Solar Energy

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## SEMCO SYSTEM 80

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## SEMCO SYSTEM 80

### 1.0 INTRODUCTION

The SEMCO SYSTEM 80 is a solar water heater developed under NASA Contract NAS8-32248 to provide domestic hot water for single family residences.

The various components of the SEMCO SYSTEM 80 are manufactured and assembled by Semco Solar Products, Inc., P. O. Box 601, Highlands, N. C. 28741 and are available on a commercial basis. Qualified mechanical contractors, architects and engineers can specify this product using the design data in this brochure.

The SEMCO SYSTEM 80 is designed to produce 80 gallons of 140°F hot water per day which is adequate for the typical family of four. Smaller or larger systems are available for families of various sizes.

### 2.0 SYSTEM DESCRIPTION

The SEMCO SYSTEM 80 is a DIRECT FEED solar water heater. Solar heating is accomplished by the circulation of potable water from the bottom of the storage tank up through the solar collectors to be heated and back down to the top of the storage tank. An electronic controller regulates the flow of water in response to the solar energy absorbed by the collectors. The electronic controller also operates the freeze protection system. This DIRECT FEED solar water heater eliminated the need for heat exchangers and anti-freeze solutions by providing freeze protection with "circulating tank water" for geographic areas below 31° latitude or "collector drain down" for geographic areas above 31° latitude.

#### 2.1 SYSTEM COMPONENTS

The SEMCO SYSTEM 80 has four subsystems as follows: 1.) Collectors, 2.) Storage Tank, 3.) Flow Controls, 4.) Transport Lines. Drawings and specifications of these various subsystems can be seen in the back of this brochure.

#### 2.2 COLLECTORS

The SEMCO Collector (Model 40-7) is a simple aluminum box with a glass face. The box is 120-11/16 inches long, 48-11/16 inches wide and 4-5/16 inches deep. The glazing consists of four pieces of 1/8 inch Lo-iron tempered glass measuring 29 3/4 inches x 48 inches. The glazing is center supported by 1 inch x 1 inch square aluminum tube mullions. The glass is bedded on PVC foam strips both top and bottom. Single glazing is standard. Double glazing is available on special order. The box is insulated with one inch foil covered isocyanurate on the bottom and 1/2 inch on the sides. The absorber plate is a manifold design with 1/2 inch hard copper

parallel tubes spaced 6 inches on center and 3/4 inch hard copper headers. The 1/2 inch tubes are finned with .010 inch hard copper plate that is grooved and continuous soldered for maximum heat absorption. The absorber plate is coated with industrial flat black enamel. The area of the collector is approximately 40 square feet.

The SEMCO SYSTEM<sup>®</sup> 80 uses two (Model 40-7) Collectors.

### 2.3 STORAGE TANK

The SEMCO SYSTEM 80 uses a 120 Gallon Solar Servant (Model RS-120-I) Storage Tank manufactured by RUDD MANUFACTURING CO. This tank is 61 3/4 inches high and has a 28 1/4 inch diameter. The shipping weight is 399 lbs. The tank holds 1,000 lbs. of water. The tank is equipped with a 6,000 watt electric booster element. Solar tanks of 82 gallon and 66 gallon capacity are available for smaller systems or can be used in tandem for larger systems. The electric booster element has the capacity to supply all the hot water needs for a family of four under normal use conditions during low solar energy periods.

### 2.4 FLOW CONTROL

The SEMCO FLO-PAC is a completely assembled water circulating and flow control system that has been factory mounted on the previously described solar storage tank. The FLO-PAC significantly reduced installation labor and assures the correct location of all components. The FLO-PAC is available in four different models.

- FLO-PAC - 1 Circulating Tank Water
- FLO-PAC - 2 Collector Drain Down
- FLO-PAC - 3 Circulating Tank Water With Breaker Box
- FLO-PAC - 4 Collector Drain Down With Breaker Box

The "breaker box" in Models FLO-PAC 3 and FLO-PAC 4 is a factory assembled prewired electric system for the controller and the booster element. A single connection to a 220 V wall outlet is the only electrical work required in the field. The controller is prewired to a 20 amp - 110 volt circuit breaker. The booster element is prewired to a 30 amp - 220 volt circuit breaker. These breakers are contained in a GE Load Center (Model TL270).

FLO-PAC 1 and FLO-PAC 3 are designed for geographic areas below 31° latitude. This area includes Florida, South Georgia, the Gulf Coast sections of Alabama, Mississippi, Louisiana, and Texas. Southern California can be included in this category. FLO-PAC 2 and FLO-PAC 4 are for the geographic area above 31° latitude.

All FLO-PAC's are equipped with a Grundfos (Model UP 25-42 SF) Stainless Steel Circulating pump rated at 1/20 H.P. and 0.85 amps. This model will pump 120 GPH at a 12 foot head which is well matched with the flow requirements of the SEMCO SYSTEM 80. All

FLO-PAC's also include a 45° check valve in the cold water up line, a thermometer and two gate valves to isolate the solar system from house water pressure.

## 2.5 Circulating Tank Water Freeze Protection

FLO-PAC-1 and FLO-PAC-3 are equipped with a Veriflo Differential Controller (Model H-1510) manufactured by Hawthorne Industries. This packet includes two heat and one freeze sensor. One heat sensor is located in the "cold water up" line as it leaves the storage tank while the second heat sensor is located in the "hot water down" line at the top of the collector. When the collector heat sensor is 3° F warmer than the tank bottom heat sensor, the controller turns the pump on and thereby activates the circulation/solar heating sequence. The greater the difference in temperature, the faster the pump turns. At a temperature differential of approximately 16° F the system is at maximum flow. Cloud cover, or night fall reverses this sequence and shuts the circulating system down. During winter months when freezing conditions occur, usually during cold nights, the freeze sensor located inside the upper part of the collector will activate the circulating system when the "in collector" temperature drops below 35° F. This feeds warm tank bottom water into the collector to prevent freezing. When the "in collector" temperature reaches 38° F, the freeze protection circulation shuts down. This sequence cycles on and off until the freezing condition is offset by the morning sun.

## 2.6 DRAIN DOWN FREEZE PROTECTION

FLO-PAC-2 and FLO-PAC-4 are equipped with a Veriflo Differential Controller (Model H-1606) manufactured by Hawthorne Industries. This model performs the circulation/solar heating sequence as described above. The freeze protection system is completely different. In this model, the controller deactivates two solenoid valves to effect freeze protection. The "in line" solenoid valve (#8210C94 by Automatic Switch Co.) is a normally closed (open when energized) valve. When the circulation/solar heating sequence is in operation, the controller energizes this "in line" valve and allows the water from the tank bottom to enter the collectors. The "drain down" solenoid valve (#8262262 by Automatic Switch Co.) is a normally open (closed when energized) valve. When the circulation/solar heating sequence is in operation, the controller energizes this "drain down" valve and prevents the system from draining down. When the circulation/solar heating sequence is on, both solenoid valves are energized. Freeze protection is accomplished by the de-energizing of these solenoid valves which occurs when the freeze sensor located inside the upper part of the collector is activated. This occurs when the "in collector" temperature drops below 35° F. This will close the "in line" solenoid valve and open the "drain down" solenoid valve allowing the water in the collectors and transport lines to drain out into a

dry well or waste line. When the "in collector" temperature reaches 38° F, the drain down sequence reverses itself and puts the circulation/solar heating sequence back into operation. Power failure will cause an automatic drain down.

During the summer months the solenoid valves remain in an energized mode for many months. This could cause the valves to stick in place and not respond to the "drain down" sequence with the first winter freeze. This problem has been overcome with controller Model H-1606. A pulse circuit has been designed into this controller that activates the solenoid valves for one second every 36 hours thus preventing solenoid valve sticking.

## 2.7 TRANSPORT LINES

The collectors, after being mounted on the roof, must be connected to the storage tank FLO-PAC by installing fluid transport lines. These lines consist of 1/2 inch soft copper tube run through the attic space. These lines must be insulated with a pipe insulation such as armaflex. The copper tube and insulation are to be supplied by the installation contractor. The sensor wire is conveniently pulled while installing the transport lines. The SEMCO SYSTEM 80 includes 100 ft. of Belden Four Conductor Shielded Cable (No. 8434) for this purpose.

## 3.0 INSTALLATION

The SEMCO SYSTEM 80 has been designed and fabricated to require the least amount of field work possible. Collectors are supplied with prefabricated mounting brackets for any flat or pitched mounting surface. Complete collector installation details are provided by sketch in the back of this brochure. Installation hardware such as bolts, spanners, pitch cups and roofing materials are to be supplied by the installation contractor.

### 3.1 COLLECTOR ORIENTATION

The collector should face due south for maximum energy collection and have a tilt angle of Latitude plus 10°. For variations from this standard see the attached paper "THE SUN AND YOUR SOLAR WATER HEATER".

### 3.2 COLLECTOR MOUNTING

When installing the prefabricated collector mounting brackets, particular care must be taken with roof penetrations. The holes drilled through the roof sheathing must be the same size as the bolts. Roofing cement must be applied between the roofing surface and the mounting angles. Pitch pans are absolutely necessary and must be filled with roofing compound. The mounting bolts must be pulled snug but not so tight so as to break the roofing surface. The installation contractor would be well advised to engage the services of a skilled roofer for the first



few installations if he is not skilled in the roofing trade. See the attached sketch for collector bracket anchoring details.

### 3.3 STORAGE TANK & FLO-PAC

The storage tank and FLO-PAC are pre-assembled and delivered as a single integrated unit. After being uncrated and placed in the proper location, two 1/2 inch soft copper lines with armafex pipe insulation are run from the FLO-PAC lines through the attic space to the mounted collectors. The sensor wires should also be pulled at this time. The 1/2 inch copper line through the attic should be strapped every 6 to 8 feet to maintain a down hill run for drain down. Again, particular care must be taken with roof penetrations. Holes drilled through the roof sheathing should be no larger than the pipe size. The 1/2 inch tube is 5/8 inch O.D. and should pass through a hole no larger than 3/4 inch. Pitch pans are absolutely necessary and must be filled with roofing compound. Standard plumbing practice and materials are used to solder the transport lines to the collectors and FLO-PAC stub outs.

### 3.4 DRAIN DOWN SYSTEM

All drain down systems must be connected to a drywell or storm drainage system. Less than five gallons of water are discharged in the drain down cycle but during freezing weather this must be disposed of below the frost line. Drain down systems must also have an air bleeder valve mounted on top of the high point of the collector array piping. This item is supplied with the FLO-PAC kit and is to be installed by the installation contractor.

### 3.5 SENSORS

The emersion heat sensor and freeze sensor must be installed in the collector, and be wired to the controller that is part of the FLO-PAC. The four conductor cable supplied for this purpose is color coded. Black and White are specified for the heat sensor. Red and Green are specified for the freeze sensor. Wiring splices must be mechanically secure and water proof. Crimp fastners and water proofing compound are provided for this purpose. Failure to properly splice the sensor wires is sure to cause the system to malfunction after 6 to 12 months of outside weather exposure.

### 3.6 BLOW-OFF (P/T) VALVE

A Blow-off (P/T) Valve must be installed at the top of the collector array. This valve may be installed with the emersion sensor and air bleeder valve using a 3/4 inch cross, tee and elbows. See the attached sketch for layout details.

### 4.0 MAINTENANCE

The SEMCO SYSTEM 80, when installed according to the manufacturers specifications, required no periodic maintenance. The

bearings of the Grundfos pump are water lubricated. The cut-off valves have brass bushings. The Solenoid valves are factory assembled and sealed. The controller is solid state.

#### 4.1 REPAIRS

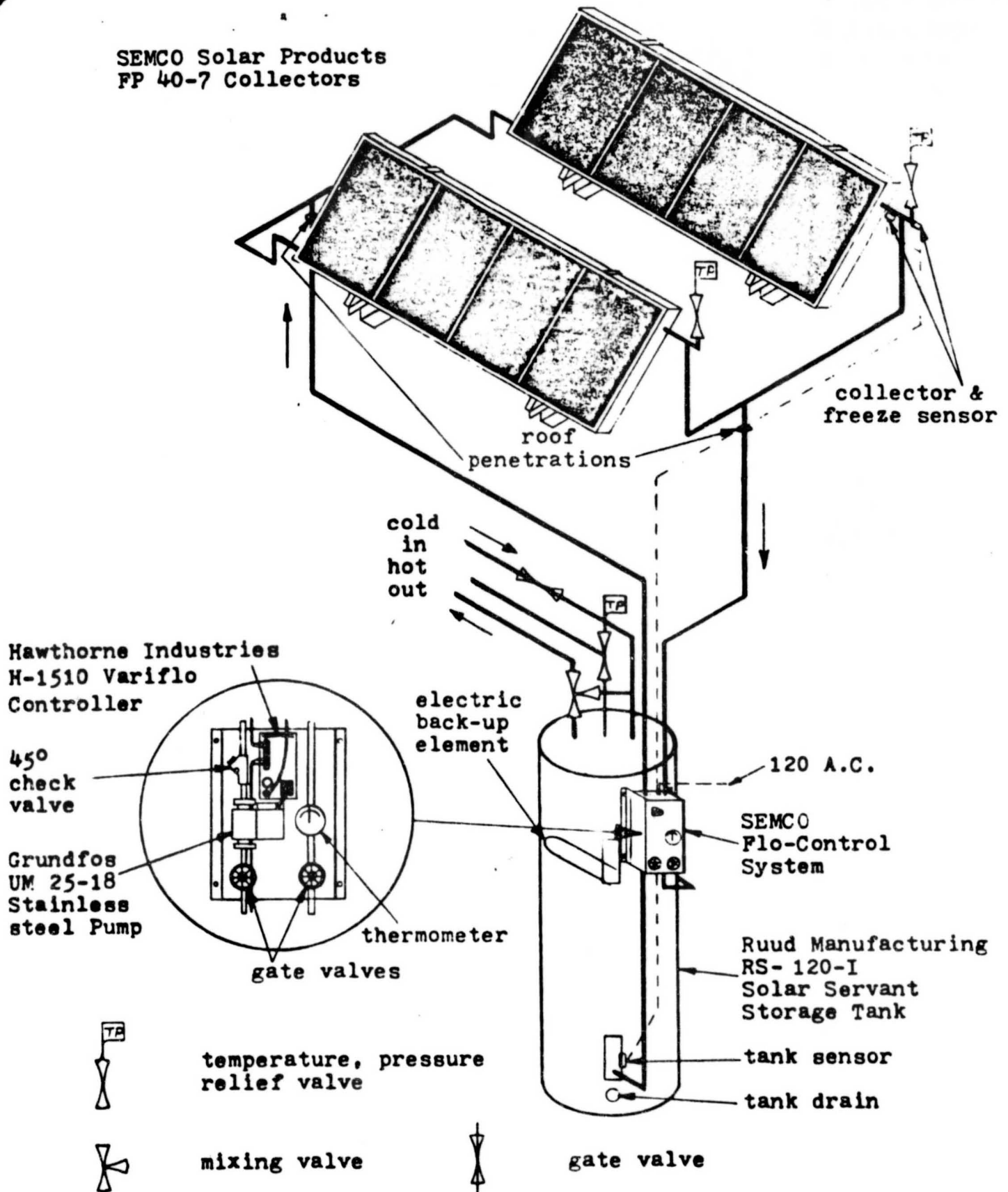
Any shut-down of the circulation/solar heating sequence will automatically transfer the hot water load requirements to the electric booster element. Should a shut-down of the system or a malfunction of any of the system components occur, the following steps should be followed.

1. Disconnect the electrical power to the controller either by unplugging the electrical cord or switching the breaker to the "off" position.
2. Close the two shut-off valves and drain the collectors and transport lines.
3. Contact a SEMCO authorized distributor or your local installation contractor.
4. Factory assistance and/or replacement parts can be obtained by writing or telephoning  
SEMCO SOLAR PRODUCTS, INC.  
P. O. Box 601  
Highlands, N. C. 28741  
Telephone 704-526-3036

# SYSTEM 80 SCHEMATIC



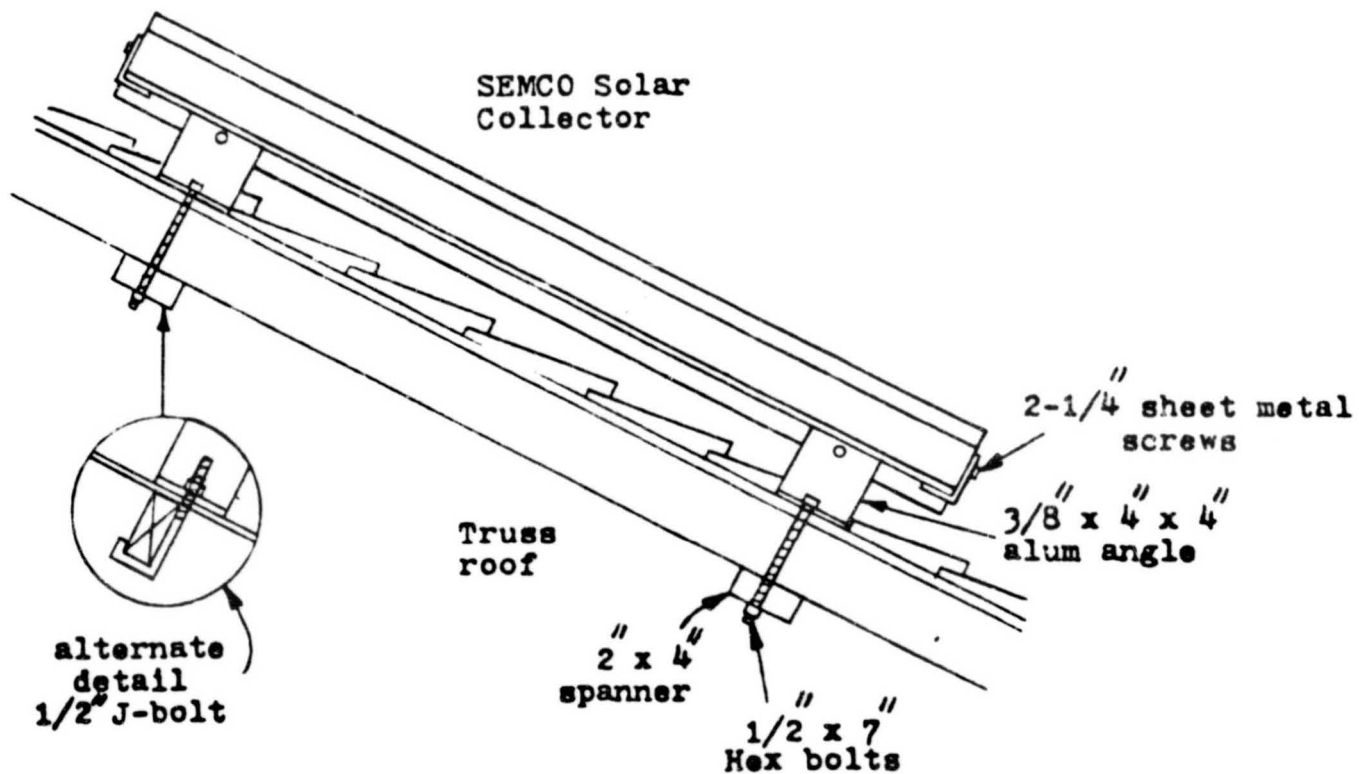
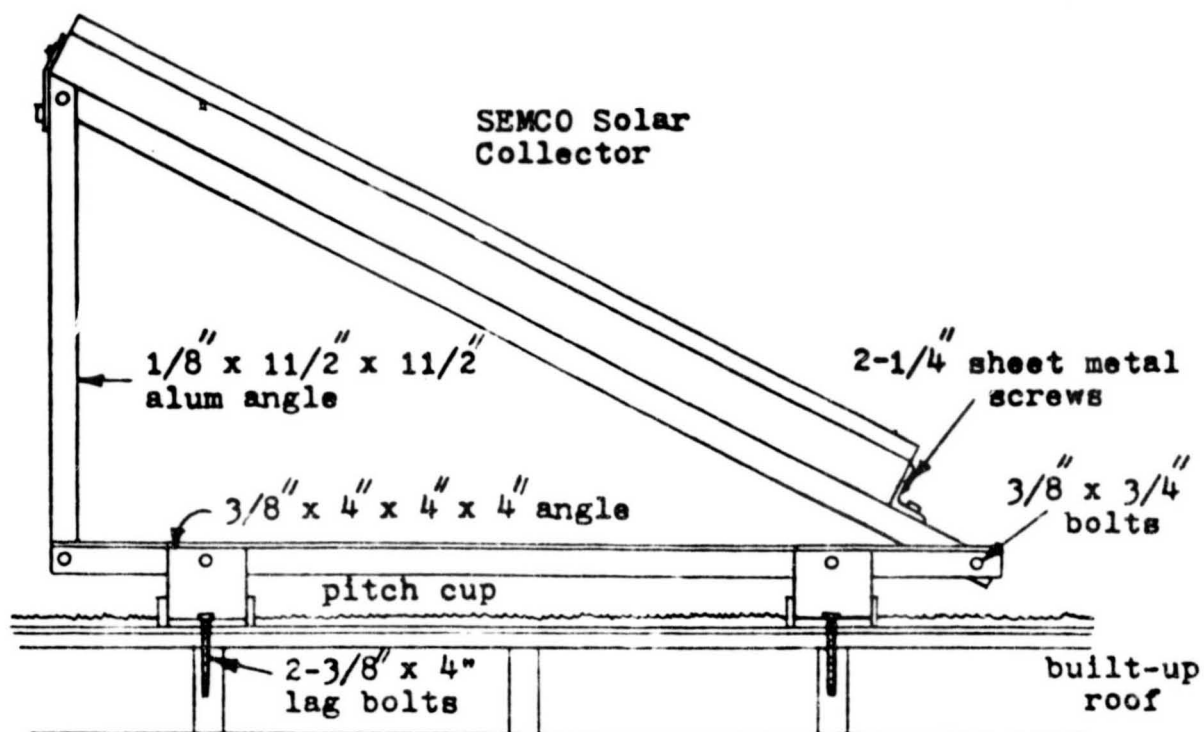
SEMCO Solar Products  
FP 40-7 Collectors







# COLLECTOR INSTALLATION DETAILS





for solar heated water storage . . .  
and electric storage water heaters

## CONSTRUCTION FEATURES

All Models — 66, 82 and 120 gallon capacities.

1. Collector Feed is located 7" above the bottom to help prevent scale or sediment from entering solar collector system.
2. Fiberglass Insulation completely surrounds glasslined tank,\* keeps water hot and conserves energy. New full wrap around jacket for improved appearance.
3. Cold Water Inlet brings cold water to tank bottom to prevent mixing with already heated water.
4. Anode Rod protects inner tank. Additional opening in top pan for easy access to anode rod.
5. Cold Water Inlet, Hot Water Outlet, Relief Valve and Anode Rod are at top of tank for easy access and fast, economical installation. New top pan securing design with coupling clamps eliminates sheet metal screws and stabilizes tank — "no floating action."
6. Side Return Opening. Located 41" from the bottom of the heater to allow for convenient installation with a gravity feed type of system.

Electric Models — 66, 82 and 120 gallon capacities.

7. Bottom pan is secured by a special lug on tank bottom eliminating need for sheet metal screws. The lug serves as a ground and also locks tank to pan to prevent "floating action."
8. Improved Electrical Junction Box (for 1/2" and 3/4" conduit) placed above heating element for easy installation. No spot welds used.
9. Direct Immersion Heating Element\*\* is completely immersed — all the heat goes into the water.
10. Automatic Temperature Control Thermostat keeps stored water at desired temperature.
11. High Temperature Limit automatically and safely cuts off power in event desired temperature is exceeded.

\*RUUDGLAS TANK Ruud water heater tanks are made with exacting care. The tank surface is coated with an exclusive porcelain formula called Ruudglas and fused to the solid steel shell at 1600°. The result is a smooth, tough, glasslike lining. Tank is designed and tested to withstand 300 PSI hydrostatic test pressure for working pressure of 150 PSI U.L. Standard.

\*\*DIRECT IMMERSION HEATING ELEMENT Nickel-Chromium heating coil imbedded in magnesium oxide and sealed in a tinned-copper tube. Although in direct contact with water, the ends are sealed to prevent entrance of moisture. Elements are changed, should the need arise, by screwing into special tank flanges.

NOTE: Unless otherwise specified standard 240 volt AC will be furnished. 120 volt, 208 volt, 277 volt and 480 volt AC supplied on special order. No extra cost (units are shipped with a 4500 watt element). If heating elements of different wattages than those shown are demanded by zone requirements they must be specifically requested.

MODEL NUMBER	CAPACITY		MAX. UL LISTED WATTAGE	UNIT DIMENSIONS				SHIPPING WEIGHT	
	GAL.	LITERS		"H"		"D"		LBS.	KGMS.
RS-66-I	66	250	6000	58 1/2	148.6	22 1/4	56.5	221	100
RS-82-I	82	310	6000	59 1/2	151.1	24 1/4	61.6	248	113
RS-120-I	120	454	6000	61 3/4	156.8	28 1/4	71.8	399	181
RS-66-T	66	250	STORAGE ONLY	58 1/2	148.6	22 1/4	56.5	221	100
RS-82-T	82	310	STORAGE ONLY	59 1/2	151.1	24 1/4	61.6	248	113
RS-120-T	120	454	STORAGE ONLY	61 3/4	156.8	28 1/4	71.8	399	181

## RUUD WATER HEATER DIVISION

CITY INVESTING COMPANY

7600 S. Kedzie Avenue/Chicago, Illinois 60652

Ruud also makes Environmental Control Products, Residential and Air Conditioning Equipment, Commercial and Industrial Heating, Cooling and Air Treatment Products



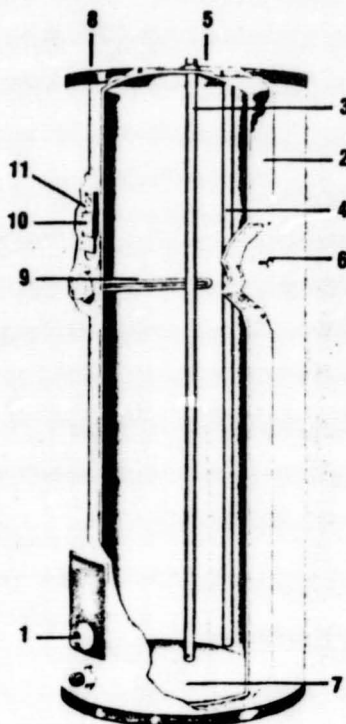
"In keeping with its policy of continuous progress and product improvement, Ruud reserves the right to make changes without notice."

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FORM NO. 102R-13 REV. 1



## LIMITED WARRANTY

GENERAL: Manufacturer THE RUUD COMPANY warrants to the Owner of this water heater that RUUD will as set forth below furnish a replacement water heater in the event of tank failure, and will furnish a replacement for any other part which is found by RUUD to have failed in normal use and service at its original installation location within the applicable periods specified because of any failure detect in material or workmanship. The RUUD replacement will be warranted for only the unexpired portion of the original warranty. However, the original warranty period will be extended to correspond with any period of loss of use of your water heater in excess of SEVEN (7) days following the notification of claim to your contractor or RUUD factory branch which may be required to effect an in-warranty replacement.

THE TANK: If the tank fails within FIVE (5) years after original installation and operation RUUD will furnish a new replacement water heater. However, if the water heater is installed in other than a single family dwelling, this tank warranty is limited to ONE (1) year from date of original installation and operation.

ANY OTHER PART: If any other part fails within ONE (1) year after original installation and operation, RUUD will furnish a new replacement part. THESE WARRANTIES WILL NOT APPLY: all to defects or malfunctions resulting from failure to properly install, operate or maintain the unit in accordance with the printed instructions provided; all to failures resulting from abuse, accident or negligence; all in the event tank failure occurs while the water heater is operated in a corrosive atmosphere or at water temperatures exceeding maximum setting of the operating and/or high limit control; or the water heater is not supplied with potable water free to circulate at all times. The tank must be free of damaging scale deposits and not subjected to pressures or fixing sales greater than those shown on the rating plate, which must not be altered, delayed or removed; all to units which are not installed in the United States of America; and in accordance with applicable local codes, ordinances and/or trade practices; all if the unit is removed from its original installation location.

SERVICE LABOR RESPONSIBILITY: In furnishing replacements, RUUD assumes no responsibility for any labor expenses for service removal or replacement. Such costs are the responsibility of the Owner, unless a service labor agreement exists between the Owner and his contractor or dealer.

WATER DAMAGE - CONSEQUENTIAL DAMAGE: RUUD shall not be responsible for any water damage. Provision should be made by Owner so that, in the event the water heater or one of its fittings, were to leak, the resulting flow of water will not cause damage to its surroundings. No responsibility is assumed for loss of use of the unit, inconvenience, loss or damage to personal property, or other consequential damage to the extent such damages are excludable under applicable state and federal laws.

SHIPPING COSTS: If in-warranty tank or parts failure occurs, RUUD will be responsible for transportation costs for the replacement to a convenient delivery point selected by it near the place of installation, such as a local Ruud water heater distributor. Owner will be responsible for any local cartage, including the cost of returning the repaired item to the local distributor.

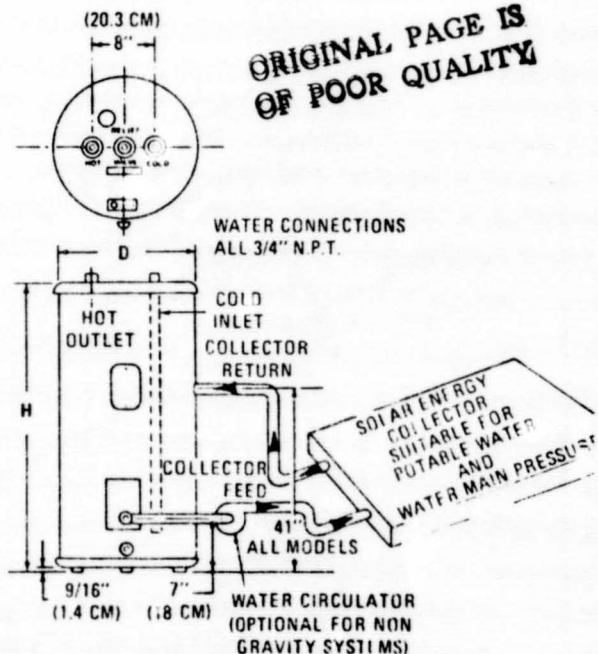
HOW TO MAKE CLAIM: Any claim under this Warranty should be made to the contractor or dealer from whom the water heater was purchased. If this cannot be done, contact any other local contractor for the replacement RUUD item, or a RUUD factory branch.

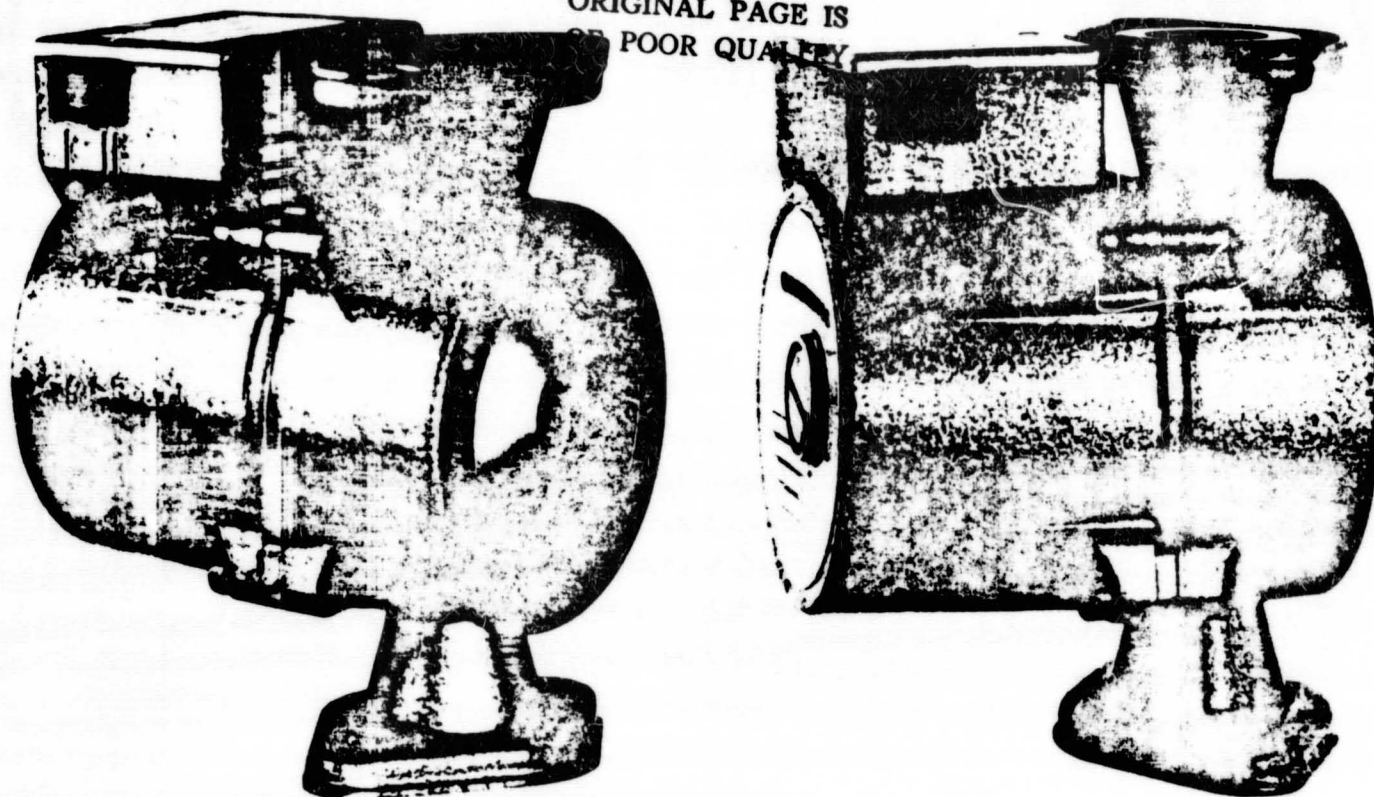
In most cases, the contractor should be able to promptly take the necessary corrective action and thereafter notify RUUD of the in-warranty claim. However, any replacements are made subject to validation by RUUD of in-warranty coverage. The item to be replaced under this Warranty must be made available in working order for the replacement.

MISCELLANEOUS: No one is authorized to make any other warranties on RUUD's behalf. Any implied warranties, including merchantability or fitness for a particular purpose, shall not with respect to the tank extend beyond FIVE (5) years or ONE (1) year if water heater is installed in other than a single family dwelling; or for any other part, beyond ONE (1) year, from the date of original installation and operation.

This Warranty shall be completed immediately and retained by the Owner for presentation in the event of in-warranty failures. In the absence of other suitable proof of installation date, the effective date of this Warranty will be based upon the date of manufacture plus THIRTY (30) days.

The above statements briefly summarize certain provisions of the Limited Warranty. Such statements are qualified in their entirety by reference to the Limited Warranty. Copies of the Limited Warranty are available without charge upon written request to THE RUUD COMPANY.



ORIGINAL PAGE IS  
OF POOR QUALITY**INFORMATION: Stainless steel circulator pump — UP 25-42 SF**

The UP 25-42 SF is a revolutionary circulator pump. The water passing through the pump touches nothing but high quality fabricated stainless steel. The volute section, for example, is constructed of type 316 stainless. As with all Grundfos circulators, the UP 25-42 SF is engineered to be interchangeable with the pumps of all other major manufacturers.

**CONSTRUCTION**

The UP 25-42 SF is a water lubricated pump. However, in order to protect the rotor and bearings from damaging impurities which may be present in the circulating water, they are separated from the stator and the pump chamber by a liquid filled rotor can. The shaft extends out from the rotor can, into the pump chamber through a shaft seal which also functions as a thrust bearing.

During initial operation the pump is automatically self-vented; however, due to the isostatic principle, there is no further recirculation of water into the closed rotor can.

The bearing construction, combined with the high starting torque of the motor, ensures re-start after shut-down.

**MATERIALS**

<b>Stainless steel:</b> .....	Pump chamber, rotor can, shaft, rotor cladding, bearing plate, impeller, variable flow adjustment plate, thrust bearing cover.
<b>Aluminum oxide:</b> .....	Top bearing, shaft ends, bottom bearing.
<b>Carbon/aluminum oxide:</b> .....	Thrust bearing.
<b>Aluminum:</b> .....	Motor housing.
<b>Ethylene/propylene rubber:</b> .....	O-rings, gasket.
<b>Silicon rubber:</b> .....	Winding Protection.

**APPLICATIONS**

The UP 25-42 SF is particularly suited for oper. and potable systems. The stainless steel construction protects the pump from the corrosion that has plagued cast iron and bronze-lined pumps in these types of applications. The pump is intended for circulation and booster applications in domestic water systems.







## PRODUCT INFORMATION

MODEL NO.  
**H-1510-A**

# VARIFLO PROPORTIONAL CONTROL

Proportional control is the outstanding feature of the H-1510-A Variflo control. This control provides an output which speed-controls pumps or blowers to produce a flow which is proportional to the collector-storage temperature differential over the range of from 3° F. to 16° F. differential.

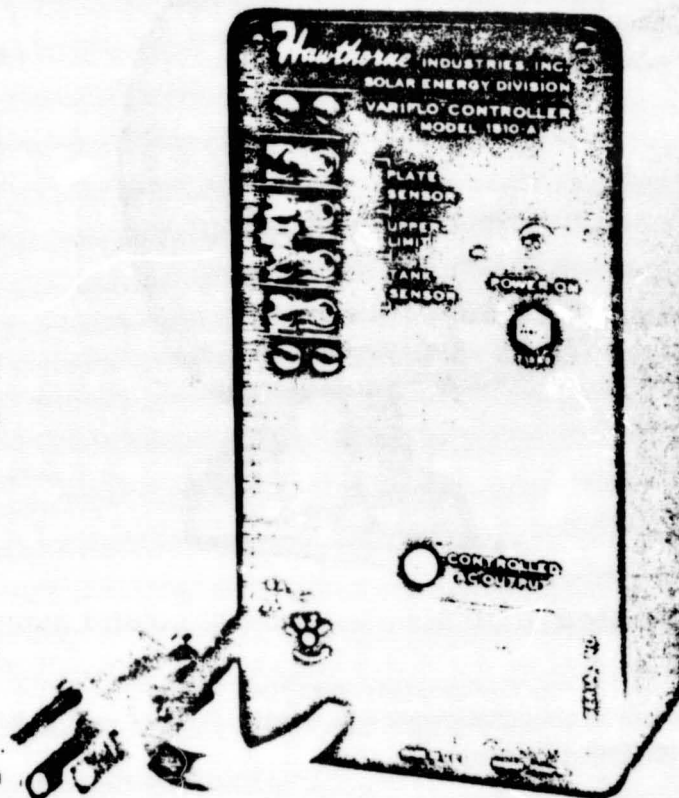
Some of the benefits realized from the use of this type of control are:

1. Proper flow rate through the system is automatically established, eliminating the need for flow adjustments as well as the hardware required to make those adjustments.
2. System cycling is virtually eliminated.
3. The circulator pump or blower receives only the amount of power required to efficiently operate the system, resulting in a power savings.
4. System efficiency may be raised by as much as 16.7% due to earlier start-up and later shut-off of systems using Variflo control.

The H-1510-A is designed to be used only with those pumps and blowers which have been tested and approved by Hawthorne Industries, Inc. for use with proportional control. Use of other equipment with proportional control may cause damage to the equipment or the control. Please consult Hawthorne Industries, Inc. for list of approved equipment.

Upper temperature limit and recirculating frost cycle protection are available with the appropriate optional sensors. Any number of sensors may be wired in parallel (frost) or in series (upper limit) for simultaneous monitoring of multiple points.

Also available with dual parallel outputs (model #H-1512-A).



### SPECIFICATIONS:

- Power requirement: 4 watts
- Power supply regulation for stable operation on line voltages from 105-130V AC, 60 Hz.
- Transformer isolation from power line, 1600V.
- Thermistor sensor voltage 8.3V DC. Maximum short-circuit current: 4.15 ma.
- All sensor terminals are short-circuit overload protected.
- Controlled AC output: 6 amps (720 watts) at 120V AC, overload protected with 6A 3AG fuse.
- Varistor line spike and lightning protection.
- Zener diode static charge bleed-off protection at sensor terminals.



## SOLAR ENERGY DIVISION

CONTROL SYSTEMS • RESEARCH & DEVELOPMENT

1501 South Dixie • West Palm Beach, Florida 33401 • Phone 305 / 659-5400

ORIGINAL PAGE IS  
OF POOR QUALITY

## THE SUN AND YOUR SOLAR WATER HEATER

### EARTH ROTATION AND SOLAR ENERGY

To apply the design principals for Solar Water Heaters, the designers must have a thorough knowledge of the earths rotation as it relates to the sun. In our solar system, the sun is a fixed point with the earth rotating around it. For the purpose of this study, we will use the earth as a fixed point and assume that the sun moves to create the daily and seasonal variations of solar energy.

We must first review our lessons in high school geography. The following sketch shows our earth with its three imaginary lines, the tropic of Cancer, the equator and the tropic of Capricorn. On March 21, the beginning of Spring and on September 21, the beginning of Fall, the sun is positioned over the equator. On June 21, the beginning of Summer, the sun is over the tropic of Cancer - which is just South of Key West, Florida in the Straits of Florida. On December 21, the beginning of Winter, the sun is over the tropic of Capricorn which is just South of Rio de Janeiro, Brazil.

The latitudes of these imaginary lines are as follows:

Tropic of Cancer	23 1/2 Degrees North
Equator	0 Degrees
Tropic of Capricorn	23 1/2 Degrees South

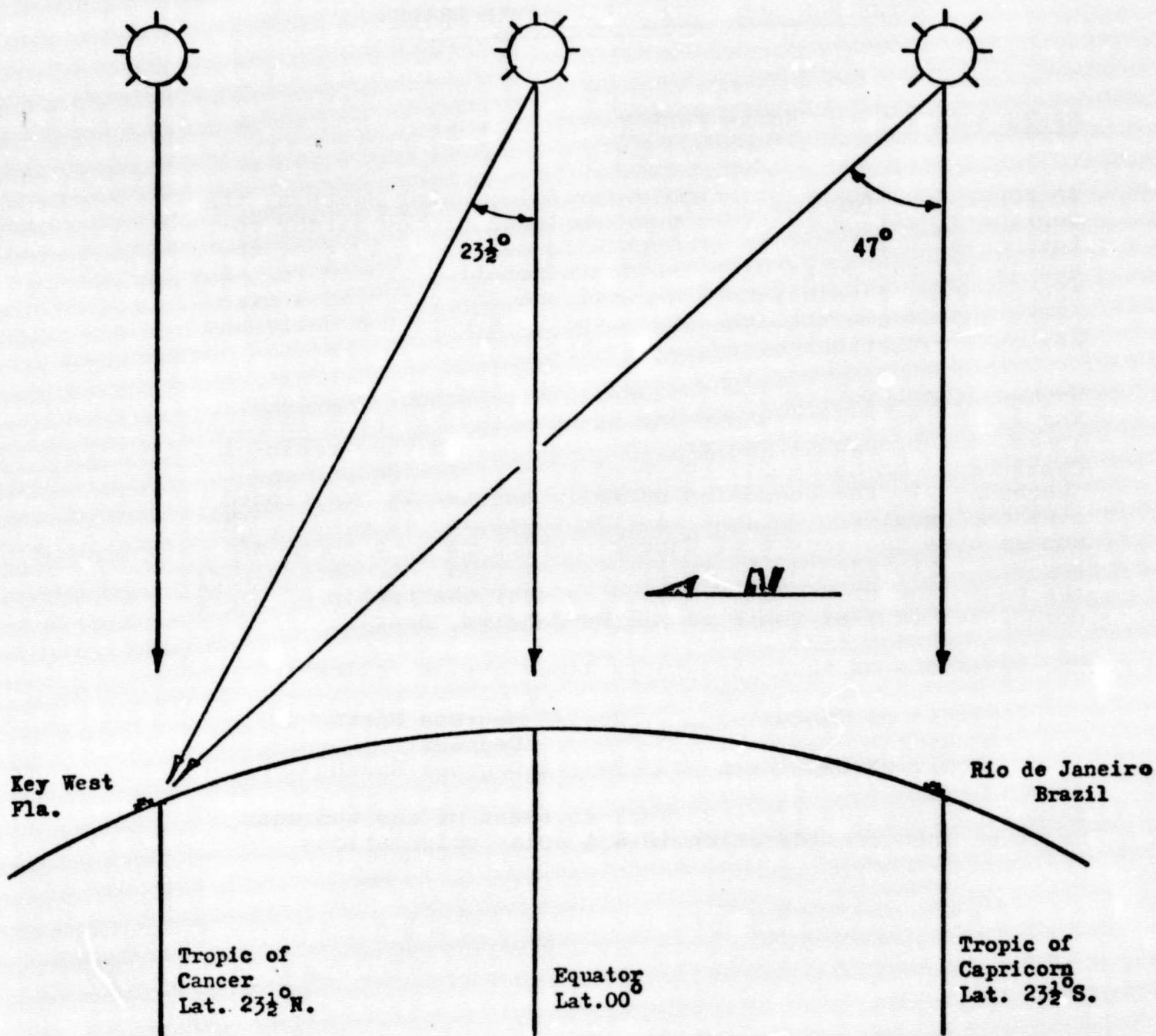
This 47 Degree ( $23\frac{1}{2} + 23\frac{1}{2}$ ) movement of the sun must be taken into consideration in all solar calculations.

Semco Solar Products  
P. O. Box 601  
Highlands, N. C. 28741  
Phone 704-526-3036

June 21 st

Mar 21 st & Sept 21 st

Dec 21 st



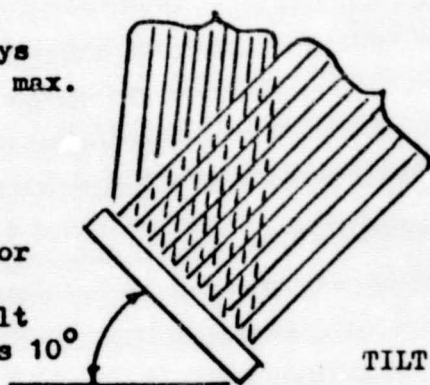
SUN POSITION TO EARTH ROTATION RELATIONSHIP

Summer Sun Rays  
70% to 80% of max.

Winter Sun Rays  
90% to 100% of max.

Solar Collector

Fixed Tilt  
Lat. plus 10°



TILT ANGLE TO SUN RAY RELATIONSHIP



## SOLAR INSOLATION

Incoming solar energy or solar radiation is now referred to as simply "insolation". It is basically a measure of heat. Current technology used the British Thermal Unit of BTU as the measure of insolation. A BTU is the energy required to raise one pound of water one degree fahrenheit. Mechanical water heaters are rated in therms or kilowatts which are easily converted to BTU's which makes the comparison between solar and mechanical water heaters simple and direct.

Insolation is a function of the following factors:

- 1.) Time of day
- 2.) Seasonal position of the sun
- 3.) Cloud cover and air pollution
- 4.) Latitude

Each factor has a specific effect on the daily usable insolation. This study will deal only with the end results of the many variables. It is recommended that a national seasonal insolation average of 1,250 BTU's per sq. ft. per day be used in solar water heater calculations. This assumes a zero Azimuth angle and a Latitude plus 10 degrees tilt angle. A typical solar water heater collector array of 80 sq. ft. will receive an insolation of 100,000 BTU's (1,250 x 80) per day on the face of the collector array.

## SOLAR COLLECTOR EFFICIENCY

Solar Collector Efficiency is a function of the following factors:

- 1.) Absorber tube size and spacing
- 2.) Absorber plate material
- 3.) Absorber plate surface
- 4.) Collector box insulation
- 5.) Collector box glazing

Each factor has a specific effect on the collector efficiency. This study will deal only with the end results of the many variables. It is recommended that a collector efficiency of 50% be used in solar water heater calculations. This assumes an absorber plate made of 1/2 inch finned copper tube on 6 inch centers painted with a black nonselective surface and a collector box made with 1 inch technifoam insulation and single glazed with Lo-iron tempered glass.

Here again an average must be used. The SEMCO collector has an approximate 70% efficiency when operating in the 90-100° F temperature range and an approximate 30% efficiency when operating in the 160-170°F temperature range. The recommended 50% efficiency average assumes an operating temperature range of 130-140°F.

### SOLAR COLLECTOR AZIMUTH ANGLE

To maximize solar energy collection, the solar collector should face due South. However, if the South facing orientation is difficult because of the collector mounting surface, the collector may face East or West of South with some resulting loss in energy collection. This loss can be estimated in accordance with the following schedule.

<u>Collector Facing</u>	<u>Azimuth</u>	<u>Loss</u>
South	0°	0%
15 Degrees E. or W. of S.	15°	2%
30 Degrees E. or W. of S.	30°	7%
45 Degrees E. or W. of S.	45°	15%

To compensate for a significant Azimuth angle, the collector area should be increased to offset the calculated loss.

### SOLAR COLLECTOR TILT ANGLE

To maximize solar energy collection, the solar collector must be mounted at an angle (tilt) from the horizontal to correspond with the position of the sun so that the face of the collector is perpendicular to the sun's rays. For example, in Columbus, Ohio which has a latitude of 40 degrees, on March 21 and September 21 when the sun is over the equator, the tilt angle would have to be 40 degrees for maximum solar collection. To maintain the maximum collection position, the tilt angle would have to be changed every few weeks as the sun moved through its 47 degree arc. This is obviously impractical, so a rule of thumb of Latitude plus 10 degrees for tilt is recommended for all year round solar water heaters. At this angle, the collector face will be approximately perpendicular to the sun in the winter months when the solar radiation is the weakest. In the summer months, when the solar radiation is more intense, the collector is less perpendicular to the sun's rays and collects a reduced percentage of the more intense radiation. The Latitude plus 10 degrees tilt angle design principle produces an energy collection pattern that tends to average the monthly solar radiation variations. The preceding sketch shows the tilt angle to sun ray relationship.

There are some exceptions to the Latitude plus 10 degrees tilt angle positioning for solar collectors. Where the solar hot water heaters are used for summer applications such as air conditioning in southern states or swimming pool heating in the northern states, a tilt angle of latitude minus 10 degrees is recommended which causes the solar collector face to be approximately perpendicular to the sun's rays during the summer months thereby effecting maximum solar energy collection during the period of maximum need.



## SOLAR WATER HEATER SIZING

Solar water heater sizing is a function of the following factors:

- 1.) Load
- 2.) Solar insolation
- 3.) Solar collector efficiency
- 4.) Solar storage capacity

To calculate the correct size for a Solar Water Heater, the designer must first determine the load or gallons of hot water to be supplied. The national average hot water load is estimated to be 20 gallons per person per day. A typical family of four will use 80 gallons of 140°F hot water per day.

Next, the temperature of the incoming water supply, which is referred to as street water, must be established. Here again there is a wide geographic and seasonal variation. This study recommends the use of 65°F street water.

With the preceding assumptions, the designer must now deal with the BTU's required. The 80 gallon load converts to 667 lbs. (80 x 8.33) of water that must have a temperature increase of 75°F (140°F - 65°F). The required heat load is 50,000 BTU's (667 lbs. of water x 75°F delta temp.) per day. Referring to the previously described national seasonal insolation average of 1250 BTU per sq. ft. per day and the previously described collector efficiency of 50%, it is possible to calculate the area of solar collector required to produce the 50,000 BTU per day heat load as follows:

$$\frac{50,000 \text{ BTU/day}}{1250 \text{ BTU/sq. ft./day} \times 50\% \text{ eff.}} = 80 \text{ sq. ft.}$$

This 80 sq. ft. of solar collector will produce the required 80 gallons of 140°F hot water per average day. On clear sunny days, the performance will exceed the designed BTU output and on cloudy cold days the performance will be less than the designed BTU output. To compensate for this day to day variations in BTU output, it is recommended that the solar hot water storage tank have a 120 gallon capacity. This 50% extra storage volume will tend to average the daily variable BTU output and more nearly provide the typical family of four with the 80 gallons of hot water required.

## AUXILIARY ENERGY

In any given year, there will be weather conditions that will not provide the needed insolation to drive the solar system. During these periods of low BTU output, an auxiliary energy system must be used. The SEMCO solar storage tank is equipped with a 6000 watt electric booster element that can provide the needed 80 gallons of hot water when the solar collectors cannot. This booster element operates automatically as in the

standard electric hot water heater. The home owner will experience no interruption in their hot water supply under normal load conditions.

#### SUMMARY

All Solar Water Heaters convert solar energy into hot water and all Solar Water Heaters have Auxiliary Energy Systems. The electric booster is the salvation of the Solar Water Heater during periods of low insolation but it is also the "cover up" for the poorly designed Solar system. The designer should provide the home owner with his estimate of the percentage of hot water supplied by solar energy. If the designer has used a reasonable BTU valve for insolation, has realistically estimated his load, has calculated an adequate collector area and has recommended extra storage capacity, he will be able to say to his client, "You can expect 80% to 90% solar participation". An inadequately sized Solar Water Heater will provide the required hot water load but may have only 30% to 40% solar participation. The designer should be able to say to his client, "Turn your booster off. You'll only need it when the weather's bad".